RELATION BETWEEN TOPOGRAPHY, SOIL CHARACTERISTICS, AND THE SITE INDEX OF WHITE OAK IN SOUTHEASTERN OHIO

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Introduction

Information on the inherent capability of land to produce forest crops is of interest and value to forest owners and managers. It is helpful to know, for example, the potential of open or cut-over lands in terms of ultimate yield of a given tree species or forest type, the rate at which plantations or immature stands will grow on a given area, and the time required for young timber to reach merchantable size.

Data on land capability are also needed for dividing forest lands into comparable compartments for experimental purposes.

The best information on site potential is obtained directly from the yield records of forests which have been managed long enough to provide reliable data. Land capability can also be determined indirectly with a fair degree of accuracy from estimates based on the growth and other characteristics of existing stands if they are fairly well stocked. However, these methods have limited application in many parts of the country, especially in the central hardwood region. Good yield records are scarce and most of the existing stands are so poorly stocked that they can not be used to measure the productivity of the sites they occupy.

In recent years research workers have explored a number of alternative methods including site estimates based on such permanent factors as soil and topographic characteristics. The soil, its profile, and its relation to topography are known to affect the growth of forest stands. This has been shown by the work of Auten (1), Coile (3), and others (4 and 7). The depth of the A horizon has consistently been found to influence growth. Other properties of surface soil horizons, such as texture and amount of organic matter have been found significant by some investigators (1 and 7).

Subsoil properties, such as permeability, plasticity, and depth, also affect tree growth (1, 3, and 4), but the influence of subsoil characteristics is imperfectly understood. For example, Coile (3) has found that loblolly pine grows slowly on Piedmont soils of high imbibitional water values, while Gaiser (4) has shown that higher imbibitional water values are associated with more rapid growth of this species on the southeastern Coastal Plain.

This irregularity is explained by differences between the topography of the two regions. In the first case the heavier subsoils occurring on pronounced slopes permit rapid lateral flow of water which is lost for plant growth. On the flatter land of the Coastal Plain lateral flow is at a minimum and the heavier subsoils reduce the amount of water lost through percolation. The more plastic subsoils, in themselves, are a less favorable medium for root growth; however, by slowing the downward movement of water, they increase the effectiveness of the surface horizons as a growth medium. Generalizations concerning the influence of surface soil horizons on growth are more apt to hold among the several forest regions (excepting the regions where cemented A horizons are common) than are similar generalizations based upon subsoil properties.

The effect of topographic differences on growth is well known. It is difficult to express these differences quantitatively, however, because land is usually classified by its exposure or it is partitioned into ridges, slopes, and bottomland. What is needed is a method of describing topography in numerically continuous units. This need is only partially satisfied by present practices; no adequate unit is available for describing on-slope position.

The Region

Southeastern Ohio lies within the lower Appalachian plateau where the relief varies from rough hilly to smoothly rolling. Slopes vary from 5 to 20 chains in length; they average about 12 chains. Slopes of 25 to 40 percent are common.

The climate is moderate; about 180 frost-free days can be expected each year. Yearly precipitation, nearly all in the form of rain, averages 40 inches.

The soils investigated in this study belong to the gray-brown podzolic group and are derived from sandstones and coarse-textured shales. Muskingum, Wellston, and associated series are dominant. These upland soils are poor to fair for growing agricultural crops. The soil has been damaged by erosion on most of the cleared land.

The forest cover is dominated by the oaks. White oak (*Quercus alba* L.), scarlet oak (*Q. coccinea* Muenchh.), black oak (*Q. velutina* Lam.), and chestnut oak (*Q. montana* Willd.) occur in pure or mixed stands. As a result of clear cutting to obtain wood for charcoal, there are extensive areas of even-aged stands. White oak is the most important timber tree of the region.

Field and Laboratory Methods

The observations for this study were made on 51 one-fifth-acre circular plots enclosing a single soil type and a surface soil of nearly uniform depth. The plots supported pure or mixed, even-aged stands of white oak more than 30 years old. The distribution of plots according to their age and stocking is shown in table 1.

Table 1.--Age and stocking of one-fifth-acre circular plots used in the white oak site index study

Stocking norm (Percent)	Age in years								Total
	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 to 89	90 to 99	100+	
	Number of plots								
Under 70	0	1	0	0	0	0	0	0	1
70 - 79	0	0	0	1	0	1	0	1	3
80 - 89	1	0	1	1	4	1	1	0	9
90 - 99	0	2	6	1	2	0	0	2	13
100 - 109	1	5	2	2	2	3	0	0	15
110 - 119	2	0	1	0	1	0	1	2	7
120 - 129	0	0	1	0	0	0	2	0	3
Total	4	8	11	5	9	5	4	5	51

Heights of three to nine dominant and codominant white oak trees per plot were measured with an Abney level and their total age at breast height was obtained from cores taken with an increment borer. Mean stand age was taken as the average age breast height plus three years. All trees reaching breast height were tallied by 1-inch diameter classes so that stand density could be estimated (2). A site index (height in feet of dominants and codominants at age 50 years) was assigned to each plot in the usual fashion except that a correction for variation in height growth caused by differences in stand density was applied (6).

The soil profile was described with respect to the texture, consistency, color, and mottling of the horizons. The depth of horizons was measured with a soil auger at 20 points. Composite soil samples were obtained for each horizon from four post-holes. Topographic features measured were the position of the plot with respect to the nearest ridge line and stream line, its exposure,1/ and the topographic slope or pitch of the plot.

Air-dry soil samples were prepared for analysis by sieving through a 2 millimeter screen. Subsamples for analysis were obtained by use of a chute-type sample splitter. Mechanical analysis (hydrometer method) and moisture equivalent (centrifuge method) were determined for all samples. Wilting percentages using wheat plants as indicators were obtained for certain horizons of about two-thirds of the plots. These data, in turn, were used to determine or to estimate the availability of water for plant growth (5).

Results

The quality of land for white oak growth is highest on the lower slopes and decreases rapidly in the vicinity of the ridge line (fig. 1). Superior sites occur on northeastern exposures and inferior sites are found on the southwest and west (fig. 2). The pitch or slope of the land does not appear to influence its quality (fig. 3).

Site quality increases as the depth and the total available moisture in the A horizon increase, but at a decelerating rate (figs. 4 and 5). Because depth is the most important factor influencing the total available moisture in the A horizons studied, depth can be accepted as a virtual synonym for total available moisture in the following analysis and discussion.

Subsoil properties have slight influence on site quality. An inverse relation between site quality and the total available moisture in subsoil horizons (to a depth of three feet) might exist. The trend displayed in figure 6 is not strong when judged in terms of the weight of the class means. Because only the first three feet of the soil profile were used in computing moisture availability in the subsoil, the availability in the subsoil must decrease as the depth of the A horizon increases. The effects of the other subsoil constants--moisture equivalent and texture--are not significant at the 5 percent level.

1/ Four plots extended over ridges. These ridge areas resembled the adjacent southwestern exposure more nearly than the other exposures and therefore were assigned to the class of southwestern exposures. A single plot fell upon dead-level bottomland and on the same basis this plot was classed with northeastern exposures.

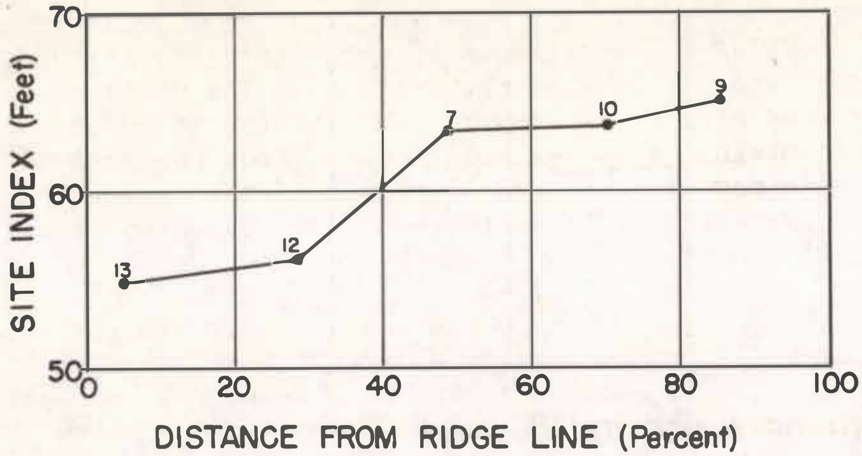

Figure 1.--The relation of white oak site index to the distance of the plots from ridge lines.

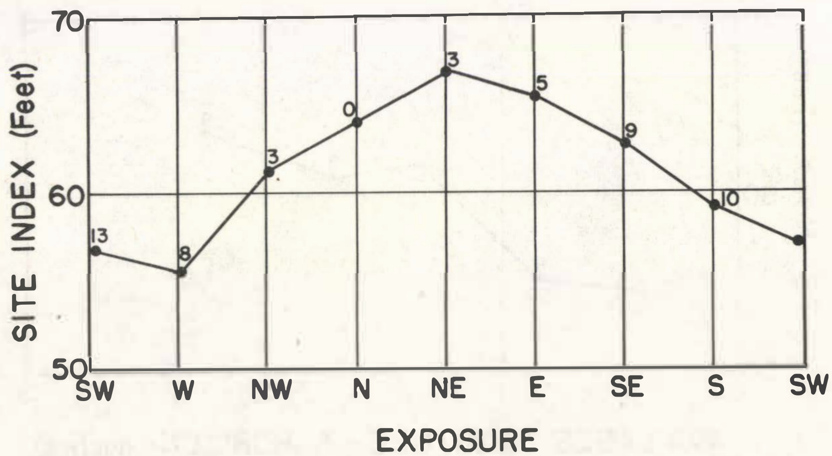

Figure 2.--The relation of white oak site index to the topographic exposure of the plots.

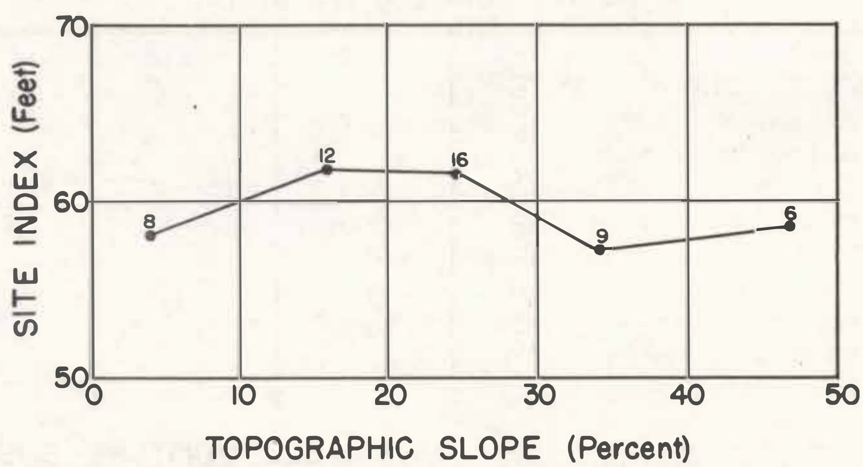

Figure 3.--The relation of white oak site index to the topographic slope or pitch of the plots.

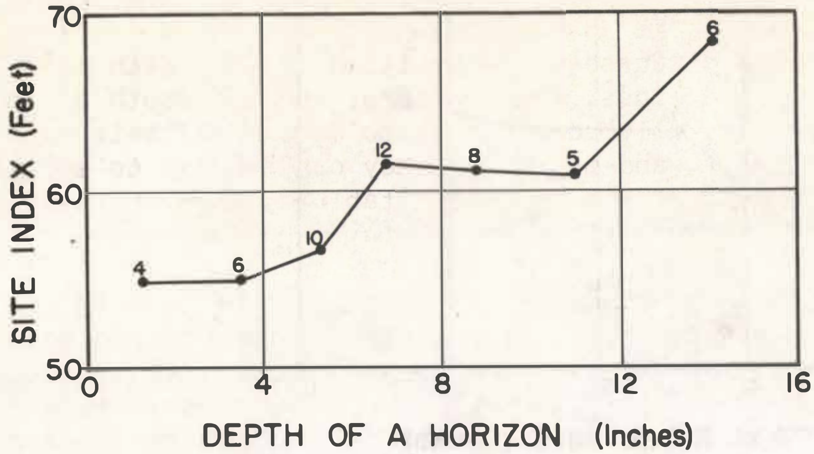

Figure 4.--The relation of white oak site index to the depth of the A horizon.

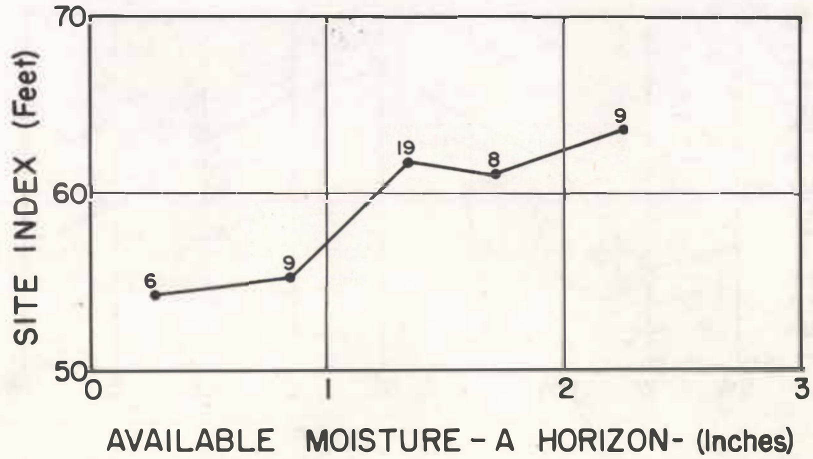

Figure 5.--The relation of white oak site index to the total available moisture in the entire A horizon covering the plots.

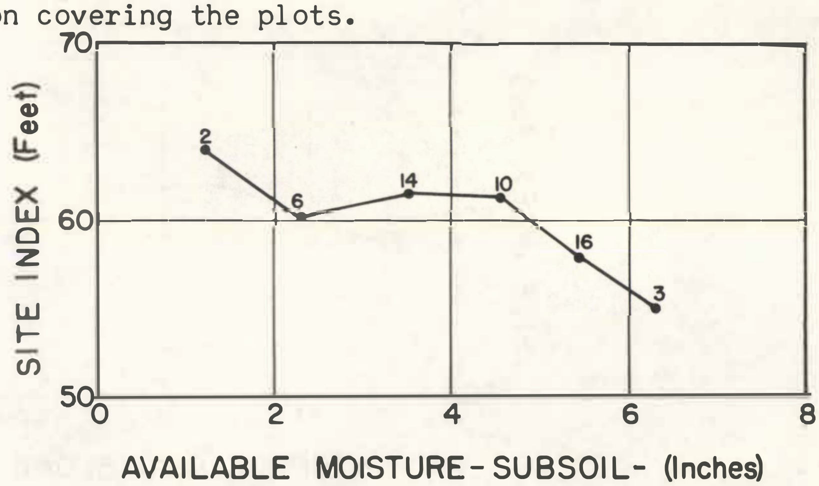

Figure 6.--The relation of white oak site index to the total available moisture in the subsoil where only the top 3 feet of the soil mantle are considered.

Of the variables discussed, the position of land with respect to ridge and stream lines, the exposure, and the depth of the A horizon were more carefully scrutinized to determine their joint influence on site quality and to see if they can be used to estimate site index. The results of the analysis (table 2) show that the contributions of all three variables are significant.[2/]

From the statistical viewpoint, the position of land is the most important variable affecting site quality; exposure and the depth of the A horizon are of second and third importance, respectively. This sequence should not be considered as necessarily a proper one because it is influenced by the accuracy of measurement of individual variables. For example, exposure can be quite accurately measured with a magnetic compass while the depth of soil horizons are measured with less accuracy where horizon boundaries are diffuse. The error introduced by the coarseness of measurement can detract from the real importance of a variable.

2/ The independent variables are required to be linear with respect to site index. This was done by expressing

1. site index as its logarithm to the base of 10:

$$Y = \log SI$$

2. the slope position as the logarithm of the reciprocal of the percent distance from the ridge line:

$$x_1 = \log \frac{1}{\text{percent distance from ridge line}}$$

3. exposure as the sine of the azimuth taken clockwise from southeast and adding one:

$$x_2 = \text{sine (azimuth from SE)} + 1$$

4. the A horizon depth in inches as its reciprocal:

$$x_3 = \frac{1}{\text{depth in inches}}$$

The resulting equation is:

$$Y = 1.837 - 0.036\ x_1 - 0.020\ x_2 - 0.051\ x_3$$

This equation is used in computing the site indices in table 3.

Table 2.--The significance of the effect of topography and soil upon the quality of land for the growth of white oak in southeastern Ohio

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio	Level of significance
					Percent
Position of land (with respect to ridge and stream lines)	1	.0342	.0342	17.1	1
Residuals from the one variable regression	49	.0958	.0020		
Position and exposure of land	2	.0480	.0240	14.1	1
Additional contribution of position and exposure jointly over position alone	1	.0138	.0138	8.1	1
Residuals from the two variable regression	48	.0820	.0017		
Position and exposure of land and the depth of the A horizon	3	.0586	.0195	13.0	1
Additional contribution of position, exposure, and depth jointly over position and exposure alone	1	.0105	.0105	7.0	5
Residuals from the three variable regression	47	.0714	.0015		
Total (corrected to mean)	50	.1300			

Discussion

Two questions might be raised in regard to the results obtained: (1) Why do topography and soil influence site quality and (2) to what practical use can the results be put? Quite simply, white oak grows better on the sites from which it can get more moisture and these are lower slopes and northeasterly exposures. White oak growth on upper slopes and southwesterly exposures is limited by moisture. Because small roots are more heavily concentrated in the A horizon than in the subsoil, a deeper A horizon permits a greater and more effective root system to develop and, as a result, above-ground growth is more rapid.

The practical interpretation of the results is facilitated by use of table 3 where site indices are listed for several combinations of the variables. If sites having an index of 55 feet or less are taken as poor sites, the upper portion of all slopes except those facing north, northeast, or east are poor sites despite the depth of the surface soil. Even the more favorable exposures will provide poor sites if the surface soil depth is 2 inches or less. Average sites occur over a wide range of conditions, but superior sites (index 65 feet or better) are found on the lower slopes of north, northeast, east, southeast, and northwest exposures if the surface soil is sufficiently deep. Superior sites are also found on upper slopes if the exposure is favorable and the A horizon deep. The line of average site index (60 feet) passes through the points tabulated below:

Distance from ridge line (Percent)	Exposure	A horizon depth (Inches)
33	SW	16
33	S and W	8
33	SE and NW	2 to 4
66	SW	4
66	S and W	2 to 4
99	SW	2 to 4
99	S and W	2

The range of site indices reported in table 3 covers 18 feet. This difference in site index results in a yield difference of about twelve thousand board feet per acre at 100 years (table 4). It is apparent that very slight differences in site quality have a great influence upon yield. Land with a site index of 68 is twice as valuable as land of site index 50 for the production of wood (disregarding the higher quality of the material obtained from superior sites). Therefore it is important to know the accuracy of the

Table 3.--Site index of white oak as related to exposure, depth of A horizon, and distance from ridge line in southeastern Ohio

Exposure	Depth of A horizon	Percent of slope length from ridge line: 1	33	66	99
		Feet			
SW	2	50	57	58	59
	4	52	58	60	61
	8	52	59	61	62
	16	53	60	61	62
S and W	2	51	58	59	60
	4	52	59	61	62
	8	53	60	62	63
	16	53	61	62	63
SE and NW	2	53	59	61	62
	4	54	61	63	64
	8	55	62	64	65
	16	55	63	64	65
N and E	2	54	61	63	64
	4	56	63	65	66
	8	57	64	66	67
	16	57	65	66	67
NE	2	55	62	64	65
	4	57	64	66	67
	8	57	65	67	68
	16	58	66	67	68

estimates found in the table. Any single estimate of site index taken from the table may be 9 percent in error.[3] A series of estimates will give a smaller error.

3/ Approximate percent error = $\pm\ 100\ [\text{antilog (mean square residual from regression)}^{\frac{1}{2}} - 1]$

Table 4.--Yield of upland oaks by site index and age[1]

Site index (Feet)	Age (Years) 50	75	100
	- - - - - - - M bd. ft. per acre[2] - - - - - - - -		
50	3.2	9.3	14.7
51	3.6	9.8	15.1
52	3.8	10.2	15.7
53	4.2	10.7	16.3
54	4.5	11.2	17.0
55	4.8	11.7	17.6
56	5.0	12.1	18.3
57	5.4	12.6	19.0
58	5.7	13.1	19.5
59	6.0	13.7	20.2
60	6.3	14.2	20.9
61	6.7	14.8	21.6
62	6.9	15.2	22.2
63	7.2	15.7	22.8
64	7.6	16.2	23.6
65	7.9	16.8	24.3
66	8.2	17.2	24.9
67	8.6	17.7	25.5
68	8.9	18.3	26.2

1/ Adapted from Schnur's (8) table 14 and figure 10.
2/ International rule, 1/8-inch saw kerf.

Summary

The quality of land in southeastern Ohio for the growth of white oak depends upon the position of the site with respect to the adjacent ridge and stream lines, the exposure of the site, and the depth of the surface soil. The total available moisture in the A horizon also influences site quality but this factor is closely linked with the depth of the horizon. The inclination or pitch of land does not perceptibly influence site quality. Subsoil properties have slight effect on site quality. A table based upon the near-permanent features of the site has been prepared so that indirect estimates of white oak site index can be made. Such estimates may be 9 percent in error.

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